

STUDIES OF HUMAN TWINS.

I. METHODS OF DIAGNOSING MONOZYGOTIC AND DIZYGOTIC TWINS.

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INTRODUCTION.

This is the first of a series of studies of human twins based upon a considerable collection of pairs taken from the environs of Chicago. These studies have been carried on in collaboration with Professors F. N. Freeman, K. J. Holzinger, and Mrs. Blythe Mitchell. The original objective of this research project was to secure an adequate collection of monozygotic and same-sexed dizygotic twins about whose diagnosis we could be certain. With this objective attained, it was proposed to make an intensive comparative psychological study of the two types of twins to determine, if possible, the influence of heredity and environment upon the various mental traits. This is an old and somewhat hackneyed problem, but one that has never been at all satisfactorily solved. It seemed to us, however, that all previous studies had been inadequate because methods of diagnosing the two types of twins were unsatisfactory. The one crying need then was for a satisfactory method of diagnosing monozygotic twins, and the working out of such a method was assigned to the present writer.

COLLECTION AND CLASSIFICATION OF MATERIAL.

The objective set by the collaborators in this study was the collection of fifty pairs of identical twins and fifty pairs of fraternal twins. In order to simplify our task, we decided to eliminate the disturbing factor of sex dimorphism, and therefore confined our study to twins of the same sex, pairs in which the twins were both boys or both girls.

At first no selection was practised among same-sexed twins,

but all cases were taken as they came. As each case was completed an informal vote of the three or four workers present was taken as to the category (identical or fraternal) to which the pair belonged. Rarely, if ever, was there any difference of opinion, but in about one tenth of the cases there was some uncertainty and these cases had to be studied more intensively.

It soon appeared that the collection of identicals and fraternal was not going evenly, the fraternal being more numerous. If our preliminary judgments as to their classification were accurate we would need to stop the collection of fraternal and collect only identicals during the last stages of the period of study.

When the adjudged "fraternal" mounted to fifty-two cases (consisting of twenty-four male pairs and twenty-eight female pairs) there were only forty-three "identical" (consisting of twenty-five male pairs and eighteen female pairs). The sex ratio at that time was very close to normal expectancy: forty-nine male pairs to forty-six female pairs. The question arose as to whether the proportion of identicals to fraternal was running according to theoretical expectancy.

Various methods have been used to determine the proportion of monozygotic to dizygotic twins. One method involved the examination of the fetal membranes of considerable numbers of twin births in institutions where competent observers were able to secure these important diagnostic data. Spät in 1860 reported that, in a total of one hundred eighty-four cases of twins examined as to the membranes, 24.6 per cent. were monozygotic. Brem in 1891 reported 22.7 per cent. of monozygotic twins out of one hundred twenty-six twin births. Kralin in 1891 reports 19 per cent. of monozygotic twins among one hundred twenty-seven twin births, but includes as monozygotic two opposite-sexed pairs. Tigges found in 1896, 21 per cent. of monozygotic twins among fifty-two twin births, and Quenzel in 1894 reported 20.4 per cent. of monozygotics among one hundred eighty-one pairs of twins. These percentages range from 19 per cent. to 24.6 per cent.

A second method used by several investigators for computing the proportion of identical twins is statistical in character. The best known of these methods is Weinberg's "differential method."

In 1902 Weinberg described his method as follows: "Assuming that sex is determined at the time of fertilization and that about half of all zygotes will produce males and the other half females, it follows that there will be equal numbers of same-sexed as opposite-sexed fraternal twins. If, therefore, we double the number of opposite-sexed twins and subtract the product from the total of all twins, the remainder will represent the number of monozygotic twins."

Applying this method to large masses of twin data he found that the percentage of monozygotic twins varies from 23.4 per cent. to 31 per cent., the percentage differing in different countries. This agrees rather closely with the percentages determined on the basis of fetal membranes.

Recently Knibbs (1926) has worked out a formula for computing the number of monozygotic twins in the twin population, using data taken from the census of Germany. His formula is as follows: The ratio of monozygotic twins to all twins is $(M + F - P) \div (M + F + P)$, where M is the number of ♂♂ pairs, F the number of ♀♀ pairs, and P the number of ♂♀ pairs. This method gives 24.4 per cent. of monozygotic twins in Germany from 1906 to 1911.

Applying Knibbs' method to the extensive twin data for the United States that is presented by Nichols (234,497 ♂♂; 264,098 ♂♀; 219,312 ♀♀), we discover that 26.42 per cent. of this large group are monozygotic and that nearly 42 per cent. of all same-sexed twins are monozygotic.

The question now arises as to whether our small random collection of ninety-five pairs of same-sexed twins was composed of the expected number of identical and fraternal pairs. According to our diagnosis there were forty-three pairs of identicals and fifty-two pairs of fraternal—*i.e.*, 45 per cent. identicals instead of the expected 42 per cent. This is but a small discrepancy and may have two meanings: Either the random selection of twins has brought in two or three too many pairs of identicals or else some two or three of the pairs diagnosed as "identicals" should be classed as "fraternals." It is probable that the former explanation is correct, for it is very unlikely that the ideal ratio as determined on the basis of 717,907 pairs of twins would be

realized exactly in the first ninety-five cases selected at random. In fact, the close approach to theoretical expectation actually realized is almost too close. The conclusion may then be drawn from this that our methods of diagnosing identical and fraternal pairs cannot be far astray.

In order to complete the proposed collection of fifty pairs of identicals and fifty pairs of fraternal, it was then necessary to select seven cases of certain identical twins. Two cases of fraternal were eliminated from the fifty-two cases of fraternal in order to get down to fifty cases. The two cases eliminated were chosen for the following reasons: In one case one twin had lost three fingers and his palm was so scarred that no adequate palm print could be taken; in the other case one of the twins showed up with an infected hand and no palm print could be obtained. Since, in our diagnosis of monozygosity, the palm prints were used as highly important criteria, it seems well to eliminate these two pairs in which the palm print evidence was incomplete. The two pairs eliminated were unequivocal cases of unlike fraternal twins.

We have now complete data on one hundred pairs of same-sexed twins, fifty of which have been classed as identicals and fifty as fraternal. No doubt some of our readers are wondering how we can speak so confidently about our ability to classify all of our cases as either identicals or fraternal. It may be said that the method was slow in taking shape and was arrived at only after intensive study of the materials.

DIAGNOSIS OF MONOZYGOTIC TWINS.

The majority of workers on human twins seem to have despaired of arriving at an adequate classification of twins into clean-cut categories: monozygotic and dizygotic. Years ago Thorndike found so much difficulty with his cases that he came to the conclusion that all twins belong to a single series and have a similar origin. Lauterbach, 1925, after the study of nearly two hundred pairs of twins, found himself unable to separate the same-sexed pairs with any assurance. He tentatively classified 59 per cent. of the same-sexed twins as monozygotic, a percentage much too

high, suggesting that he has included a good many cases of similar fraternal twins in his "identical" group.

The most recent study of twins is that of A. H. Wingfield (1928) who studied one hundred two pairs of twins selected at random from the public schools of Toronto and Hamilton, Ontario. Taking all pairs of twins as they came there were accumulated seventy-six like-sexed pairs and twenty-six unlike-sexed pairs. The expectation would be about 65 per cent. of like-sexed twins instead of about 74 per cent., the number found in this collection. It seems probable, therefore, that some unlike-sexed twins were overlooked. Wingfield made an attempt to separate the seventy-six like-sexed pairs into two groups, identicals and fraternal. His method was somewhat precarious. He classed as "identical" all those which seemed to himself and the teacher to have a higher degree of physical identity than siblings are likely to exhibit. "Only those pairs of twins showing practically indistinguishable physical traits, as judged by the teachers in the school and myself, were included in the identical group. While it is not absolutely certain that all pairs included in the identical group had identical heredity, the chances in favor of this being the case are very great." The fact that he classed as identical over 44 per cent. of all the twins in his group is surprising in view of the fact that the statistical expectation is only about 26 per cent. It seems probable then that Wingfield has included among the "identicals" several cases of similar fraternal twins. This is further suggested by the fact that he found a coefficient of correlation of only about $+0.90$ for this group as compared with $+0.95$ obtained for our identicals.

That it is possible to develop a method of distinguishing between identical and fraternal twins is strongly suggested by the fact that two European twin specialists claim to be able to make such a distinction with a high degree of infallibility.

Dahlberg (1926), in his monograph on "Twin Births and Twins from a Hereditary Point of View," makes this statement: "The following demands should be satisfied for a diagnosis of monozygotism for a grown-up pair of twins:

"1. That the appearance of the twins give an impression of very great resemblance or identity.

"2. That during childhood, neighbors, school-fellows, etc., have had difficulties in distinguishing them and have sometimes confused them.

"3. That the configuration of the ears does not show great dissimilarity.

"4. That the finger prints show a certain high degree of similarity.

"5. That the anthropological measurements do not show too considerable differences."

Siemen's method (1927) is somewhat more detailed and exacting. He takes the very sensible view that no single criterion of monozygotic origin is reliable, but that judgment in doubtful cases should be based upon identity in as many traits as possible. He emphasizes the rarity of really questionable cases. Many years of experience in the study of twins has developed in him such a degree of confidence in his method of diagnosis that he considers that he has been able to reach "a certain diagnosis in virtually every case of twinning."

He finds, as others have found before and since, that the great majority of all twins are either so completely alike or so markedly different that there is no question about their diagnosis. A careful study of the certain cases should furnish criteria for diagnosing the few doubtful cases. Thus a study of over a hundred pairs of unquestionable identical twins has resulted in the following "scheme" for diagnosing monozygosity:

- A. Traits in which one-egg twins practically always agree and in which two-egg twins agree only very rarely:
 - 1. Hair color and form.
 - 2. Eye color.
 - 3. Skin color.
 - 4. Downy hair of the body.
- B Traits in which one-egg twins differ only within narrow limits and in which two-egg twins usually differ more widely.
 - 5. Freckles.
 - 6. Appearance of blood in the skin.
 - 7. Follicular processes.
 - 8. Tongue (furrowed or not) and teeth.

C. Traits in which one-egg twins usually, and two-egg twins rarely show strong resemblance:

9. Form of face.
10. Form of ears.
11. Form of hands.
12. Body build.
13. Mentality.
14. Illness and abnormality.
15. Traits studied by special methods—finger prints, etc.

Our own method of diagnosis has been considerably influenced by the methods of Dahlberg and of Siemens, especially by the latter, but is somewhat different from any previously used. Our effort has been to combine the best features of all known methods.

After our own method was developed and while reading Wingfield's monograph, the writer noted a reference to a short note in *Science* by Taku Komai (1927) entitled "A Criterion for Distinguishing Identical Twins from Fraternal Twins." The criterion described has to do with finger prints and palm and sole prints of twins. "Generally speaking," he says, "the same hands or feet of the identical twins resemble each other more closely in their patterns than the two hands or feet of the same individual." This I have found to be very frequently true, but the formula needs modification, as will be shown below.

OUR OWN METHOD OF DIAGNOSIS.

The method of identifying monozygotic twins used in the present work may now be described in detail. A great deal of attention has been given to this matter, for we realize that the soundness of our conclusions as to heredity and environment depend upon the correctness of this diagnosis.

At the beginning, it may be said that in over 90 per cent. of our cases there was at no time any doubt as to their classification. The great majority of one type of twins are so strikingly similar that their monozygotic origin is obvious. Their resemblance is not confined to gross physical correspondence, but extends to tones of voice, gestures, and peculiar mannerisms. One soon becomes sensitized to the intangible correspondences of

identical twins and diagnoses them almost at a glance. The great majority of the other type of twins strike one at once as entirely unlike, often being more different than average brothers or sisters. About these there is no question after the first glance. Our ability to diagnose cases improved during the course of our study and we found that there was no difficulty at all in diagnosing the last half of the pairs that presented themselves. Two of the very early pairs were diagnosed doubtfully that, when reexamined after a year of experience, offered no difficulty at all. Two other cases were left uncertain because we allowed ourselves to be influenced by statements of the mother. About these cases there should never have been any question had the mother not been loquacious.

Out of one hundred two pairs of twins there was justifiable doubt about only six cases. These cases have all been diagnosed satisfactorily with the possible exception of No. 61, which still remains slightly uncertain.

The following are our criteria for diagnosing identical (monozygotic) twins.

1. They must be strikingly similar in general appearance including various intangible resemblances.
2. They must be essentially identical in hair color, texture and form.
3. They must have the same shade of eye color and form of iris.
4. They must have the same skin color and texture (complexion) except when one is more tanned than the other.
5. They must have no marked differences in features; shape of ears; shape, size and arrangement of teeth.
6. They must have hands of the same type and nearly equal in size.
7. The general microscopic character of the papillary ridges in fingers and palms must be essentially the same.
8. There must be stronger cross resemblance than internal resemblance in one or more of the details of finger and palm patterns.
9. The presence of reversed asymmetry in handedness or hair whorl in one twin is confirmatory evidence of monozygosity, but

its occasional presence in unlike twins is not to be taken as an indication of monozygosity.

A great deal of stress has been laid upon the diagnostic value of the palm and finger patterns. While this criterion alone is inadequate for certain diagnosis, it is surprising how few mistakes were made in our effort to diagnose monozygosity on this basis alone. In the first forty-two cases in which a judgment was attempted on the basis of palm and finger prints alone, there was disagreement in only two cases with the judgment based on general resemblance. Our method has been to classify all cases on the basis of the first six criteria and then to check this classification by criteria 7 and 8.

PALM AND FINGER PRINTS AS CRITERIA.

The intensive study of palm and finger patterns is perhaps the best single diagnostic aid. After a scrutiny of the first thirty or forty sets of palm prints the writer began to notice an important fact about the palm and finger patterns of strikingly identical twins: namely, that, instead of showing mirror-imaging of patterns (involving the resemblance of the right hand of one to the left hand of the other) the two hands of one of the twins were direct duplicates in major features of the two hands of the other. Specifically, the right hand of one twin is more like the right hand of the other than like own left hand, and the left hand of one twin is more like left hand of other than like own right hand. Thus cross resemblance between the two twin individuals is stronger than resemblance between the two hands of the same individual.

Among twins that are somewhat less alike the same rule holds in a somewhat modified form. Thus right hand of one twin may be like right of the other, or left of one like left of the other, but the close resemblance does not extend to both sides. In still other pairs of twins in which one is distinctly left-handed, there is a reversal of asymmetry, so that the right hand of each twin is like the left hand of the other. *In every pair of obviously monozygotic twins the rule holds that there is stronger cross resemblance between the hands of one twin and those of the other than between the two hands of the same individual.* The same

is true of ears, teeth, and other structures that show more or less asymmetry, but there is more detail in palm and finger prints and a more objective method of comparing them. In the case of the fingers the types of patterns have been formulated in all cases in order to obtain a qualitative basis of comparison, and the friction ridges in all patterns (following the method of Bonnavie, somewhat modified) were counted under binocular so that a quantitative comparison between the fingers of one hand and those of another is possible. In both qualitative and quantitative respects the rule that cross resemblance is stronger than internal resemblance holds, for identical twins.

The studies of palm main line formulæ and of the occurrence and varied expression of the six fundamental primitive patterns have been greatly facilitated by the study of a paper now in manuscript, the work of a considerable group of experts, entitled "A Study of Error in the Interpretation and Formulation of Palmar Dermatoglyphies," by Cummings, Keith, Midlo, Montgomery, H. H. Wilder and I. W. Wilder. Professor Cummings, evidently the guiding spirit of the group in this collaborative inquiry, has very kindly furnished me with a copy of the manuscript and has thus made it possible for me to study the palms of our twins with far greater efficiency than would have been possible without this assistance.

With few exceptions the same rules of cross resemblance apply to the palmar main lines and patterns that apply to finger prints. Most frequently the cross resemblance runs similarly in all four respects: in qualitative characters of finger patterns, in quantitative values of finger patterns, in palmar main line formulæ, and in the occurrence of palmar patterns. Sometimes the cross resemblance is obvious in only three of four respects, sometimes in two, or only one; but if it is greater between one hand of one twin and either the same or opposite hand of the other twin than in own hands, the rule is considered to hold good.

While it is of importance that the detailed analysis of the finger and palm characters of this collection of twins should be published, this is hardly the appropriate place for it. One or two separate papers devoted to a special presentation and analysis of these data are planned for subsequent publication.

At this time we must ask the indulgent reader to accept tentatively our criteria for diagnosing twins. With the publication of the complete data used in this diagnosis the methods used may be put to any test that seems necessary.

Applying the criteria of diagnosis above described to the six pairs of twins about which there was some doubt, three of them fell readily into the category of identicals and three were classified as similar fraternal. At the present time the writer feels quite confident as to the correctness of diagnosis of the whole collection. The cases that might be questioned by some are the three cases of similar fraternal just referred to. Before discussing the problems arising out of a study of identical twins, it seems advisable to devote a few paragraphs to the fraternal twins, especially to the three cases most difficult to diagnose.

THE DIAGNOSIS OF FRATERNAL TWINS.

Of the fifty-two pairs of fraternal twins in our collection, three may be classed as "similar fraternal," and twenty as "slightly similar fraternal," and twenty-nine as "unlike fraternal." None of the pairs show as much resemblance as the least similar of the identical twins. The only cases that could possibly be at all in question as to their classification are the three "similar" pairs, numbered 61, 15, and 74. Let us carefully scrutinize these rather crucial cases as to the possibility that they might be monozygotic twins of the less nearly identical sort.

Pair 61.—These girls at first impressed us with their similarity. They were dressed exactly alike, arranged their hair alike and had very similar coloring. In height there was but three eighths of an inch difference; there were two and three fourths pounds difference in weight. Head length of A was 13.95 mm., of B 14.35 mm.; head width of A was 17.7 mm., that of B was 17.9 mm. The hair of both was in general rather similar, but that of B was a shade darker, softer, finer and not so heavy. Eye color was the same in both, a type of hazel. There was no difference in skin color. Ears of A were higher and narrower than those of B, and had a shorter lower lobe. A has fuller lips; B has the longer, more prominent chin. A holds eyes wide open; B has them nearly half closed. Bridge of A's nose more bowed

than that of B. The teeth of the two differ rather sharply, the upper arch of B being narrower and the teeth crowded and irregular, while those of A are regular.

The finger print formulæ are decidedly different :

<i>Left Hands.</i>	<i>Right Hands.</i>
1, 2, 3, 4, 5	1, 2, 3, 4, 5
A—U, R, A, W, W	A—U, U, U, U, U
B—W, U, R, U, U	B—W, R, U, U, U

The quantitative values of the finger prints are :

A—right hand 24	A—left hand 28
B—right hand 38	B—left hand 25

All four palm main line formulæ are different and the patterns are also different.

<i>Left Hands.</i>	<i>Right Hands.</i>
A—(9.8.5".5') B.O.O.O.O.	A—(11.9.7 .5') B.O.O.L.O.
B—(9.8.5".3) A.O.O.O.O.	B—(9.7.5".3) C.O.O.O.O.

Both are equally right-handed and both have clockwise hair-whorl.

In spite of a superficial rather close resemblance, then, there is no indication that these twins have had a monozygotic origin. This was the most difficult case to diagnose, but there seems now no doubt that these twins are dizygotic in origin.

Pair 65.—This case was somewhat puzzling because the two girls are both rather peculiar in appearance and are similar in many peculiarities.

In height A is 57½ inches, B 56⅞ inches. In weight, A is 113¼ pounds, B is 111¼ pounds. Head length of A is 14.5 mm.; that of B is 14.4 mm.; head width of A is 17.7 mm.; that of B is 17.1 mm. Hair of both is the same in color and texture; eye color of both is of the same shade of blue; B has a lower brow and a sullen expression about the eyes, while A has a contented expression. The skin is somewhat more florid in B. The ears of the two differ greatly, B having much longer lower lobe. The hands differ in shape, those of A being broader and thicker. B has shorter, more turned-up nose, a distinctly wider mouth, fuller lips and fatter face. The teeth differ radically, the upper arch of B being wider and straighter across the front and with wider teeth.

The finger print formulæ read as follows :

<i>Left Hands.</i>					<i>Right Hands.</i>				
1,	2,	3,	4,	5	1,	2,	3,	4,	5
A—W,	R,	W,	W,	U	A—W,	W,	W,	W,	U
B—W,	W,	U,	W,	U	B—W,	W,	W,	W,	U

The quantitative values of the finger prints are:

A—right hand	53	A—left hand	54
B—right hand	52	B—left hand	60

The palm formulæ are as follows:

<i>Left Hands.</i>		<i>Right Hands.</i>	
A—(11.7.7. 3)	A.O.O.O.D.	A—(11.9.7 5')	A.O.M.O.D.
B—(9.8.5".5')	A/B.O.O.O.D.	B—(11.8.7.5')	O.O.M.L.O.

In several respects there is a little more resemblance between right palm and fingers of the two than to their respective lefts, but this does not extend to details. On the whole these two girls make an entirely different impression. One has a rather pleasing, happy expression, the other a sullen, lowering expression. The fact that B is ambidextrous in both finger and wrist tapping suggests that she might be the left-hand component of a monozygotic twin pair, but there are too many differences between them to permit such a diagnosis.

Case 74.—These girls have many traits in common, but show also some extreme differences. A's height is 59 inches; B's is 53¾ inches. A's weight was 70½ pounds; B's 66½ pounds. A's head width is 14.1 mm.; B's 13.5 mm. A's head length is 17.6 mm.; B's is 17.1 mm. Hair color, texture and crown whorl same in both. Eye color of both a gray brown, but A's eyes are distinctly grayer and B's browner. B's ears are distinctly larger and wider although her head is considerably smaller. A's eyes are wider spaced than B's. A's nose is larger, longer and different in shape. B's teeth are crowded and overlap in front, while A's are straight.

Finger print formulæ:

<i>Left Hands.</i>						<i>Right Hands.</i>				
1,	2,	3,	4,	5						
A—W,	R,	R,	U,	U	:	A—W,	R,	U,	U,	U
B—U,	R,	U,	U,	U	:	B—U,	A,	A,	U,	U

Quantitative values of finger patterns:

A—right hand	44	A—left hand	30
B—right hand	27	B—left hand	26



Palm formulæ:

<i>Left Hands</i>			<i>Right Hands.</i>	
A—(11.7.7.3)	O.O.O.O.D.	:	A—(11.9.7.3)	O.O.O.L.D.
B—(11.7.7.3)	O.O.O.O.O.	:	B—(11.7.7.3)	A.O.O.O.O.

Here again the palm formulæ suggests a closer resemblance than actually exists, in that we have the same pattern for the two left hands, but the two palms of B also have the same pattern and are far more similar in detail. Nowhere is there stronger cross resemblance than internal resemblance. On the whole there can be no doubt that these are fraternal twins.

Apart from these three cases there are no decidedly similar twins among the fifty-two pairs in our collection. Twenty pairs are designated as "slightly similar" fraternal twins and the remaining twenty-nine cases are designated as "unlike" fraternal twins. The slightly similar fraternal twins show merely the degree of resemblance common among siblings, while the unlike fraternal twins seem to show hardly as much resemblance as do average siblings. Even the three cases of decidedly similar fraternal twins, except for their identity in age, are no more alike than are occasional siblings. On the whole then, there seems to be nothing about these fifty-two cases out of accord with their classification as fraternal, or dizygotic, twins. Hence there is now no ground for doubting the validity of our classification of the one hundred two pairs of twins used in this study, into the two categories; monozygotic and dizygotic.

SUMMARY.

1. The original objective of these studies was the study of the rôles of heredity and environment in determining mental capacities of various sorts.
2. The first essential was to learn how to diagnose with certainty the two types of twins, monozygotic and dizygotic.
3. Only about 25 per cent. of all twins are monozygotic. Collections that depart widely from this figure have probably been incorrectly diagnosed.
4. Only about 42 per cent. of same-sexed twins are monozygotic.
5. The method of diagnosis used in this study combines the best

features of the methods of Dahlberg, Siemens, and Komai. Certain refinements of technique are added, the details of which are explained in the text.

6. Out of a collection of one hundred two pairs of same-sexed twins, only six pairs caused any difficulty, three of which are now classified as monozygotic and three as dizygotic.

7. The details concerning the three "similar fraternal" are presented and the reasons for their diagnosis as dizygotic twins are given.

8. The result is that we have now a collection of fifty pairs of monozygotic and fifty-two pairs of dizygotic same-sexed twins accurately diagnosed. These are to be used for further biological and psychological study.

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